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TRAPPED RADIATION AND IONOSPHERIC PERTURBATIONS DUE TO AN IMPULSIVE NEUTRON SOURCE

by

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ABSTRACT

Extensive interest has been shown in the geophysical perturbations associated with nuclear testing. Studies of the large scale displays resulting from this type of controlled stimulus may be used to shed light on the details of the mechanisms responsible for naturally occurring geophysical phenomena. Computations based on the neutron decay model postulated by Crain and Tamarkin [1961] have been carried out to evaluate the contribution of the decay products of neutrons emitted from a fission reaction to associated ionospheric disturbances and trapped radiation increases. It is shown that the fission neutron source is useful in explaining the morphology of nuclear-associated VLF effects although the amount of ionization produced promptly in the D-region may be insufficient to account for the magnitude of these effects.

Experimental evidence is also advanced to show the detection of short-lived trapped radiation from this neutron decay source. The contribution to the long-lived trapped radiation is shown to be negligible.

ACKNOWLEDGMENTS

The authors are indebted to R. Meuse of the Boeing Primary Standards Laboratory for granting permission to use some of the phase comparison records he has made between WWVL reception and the Boeing Frequency Standard. We would also like to express our appreciation to H. Liemohn for several useful discussions in the early stages of this paper.

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I. INTRODUCTION

Extensive interest has been shown in the study of the geophysical perturbations associated with nuclear testing. Studies of the large scale displays resulting from this type of controlled stimulus may be used to shed light on the details of the mechanisms responsible for naturally occurring geophysical phenomena.

High altitude nuclear detonations, in particular, give rise to aurora, cosmic noise absorption, sporadic E [Gregory, 1962], short-wave fadeout, micropulsations, magnetic disturbances [Caner and Whitman, 1962], spread-F [Heisler and Wilson, 1962], D-layer enhancements [Obayashi et. al., 1959], and other disturbances closely resembling phenomena which one notes normally in nature. Many of these disturbances can be explained in terms of debris motion and fireball expansion, others can be explained as the effects of trapped radiation, while the origin of still other disturbances is obscure.

Most of the bomb-produced radiation which becomes trapped will have been injected directly into the earth's magnetic field from the detonation site and subsequently drift around the earth in a normal fashion predictable from trapping equations [Hamlin et. al., 1961]. An additional source has been postulated by Crain and Tamarkin [1961] in the neutron decay model. A small fraction of the neutrons leaving the fission area (see Figure 1) will decay into protons and electrons before they leave the earth's magnetic field. Those neutron-decay products which mirror at high altitude will contribute to long lasting radiation belts; those which mirror at low altitude will be lost quickly; and finally an appreciable fraction will be lost in the earth's atmosphere on the first north-south penetration. This last category will be comprised of those neutron-decay products injected into the magnetic field with pitch angles such that they would mirror in or below the atmosphere.

Since the neutrons are uncharged and would have energies in the low Mev region [Watt, 1952], they can travel across field lines without being deflected and decay at regions remote from the blast site within an extremely short time. The resulting protons which spiral along the field lines and strike the atmosphere are prevented from reaching much below 80 km, but the electrons can easily penetrate farther than this.

Evidence for an extremely prompt source of ionization deep within the D-region at locations remote from a blast site exists in various VLF records taken during high altitude tests [Zmuda et. al., 1963; Willard and Kenney, 1963] and the neutron decay theory has been utilized to explain this effect. Accurate calculations should now be made to determine if the magnitude of the neutron source is sufficient to explain these D-region enhancements. Of equal interest would be a calculation of the

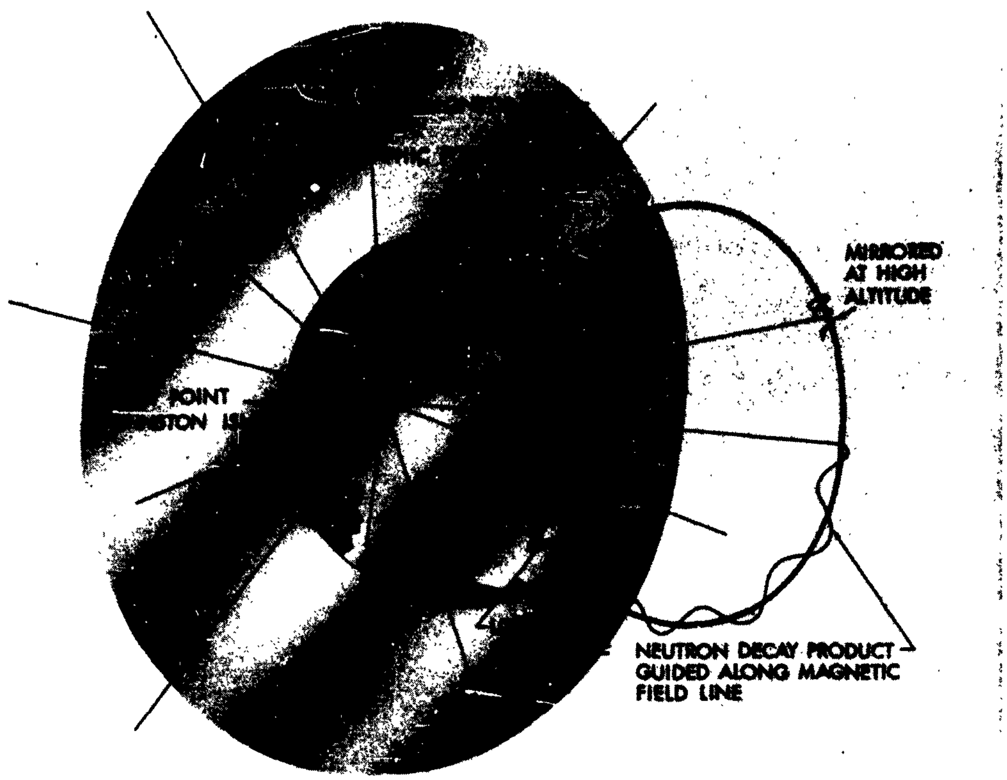

Fig. 1. Trapping and precipitation of neutron decay products within the magnetosphere.

spatial contribution to the trapped radiation from the neutron decay source.

It is the purpose of this paper to describe a calculation which has been made to evaluate the contribution of the decay products of neutrons emitted from a high altitude nuclear detonation to the trapped radiation and to prompt D-layer enhancements remote from the detonation site.

II. THEORETICAL CALCULATION

In order to determine the number, $I(\theta_d, \lambda_d, \lambda_o)$, of charged particles injected into the ionosphere above a certain point on the earth's surface from neutrons which leave a blast area and decay in the magnetosphere, we must evaluate an integral of the form

$$I\ (\theta_d, \lambda_d, \lambda_o) = \int_V N(r, \theta, \lambda)\ Y(r)\ dv \tag{1}$$

where $N(r, \theta, \lambda)$ is the number of neutrons which decay in one cubic centimeter as a function of position. $Y(r)$ is that fraction of $N(r, \theta, \lambda)$ whose decay products come out below a critical value of injection pitch angle, so that they are lost in the atmosphere on the first penetration. One must integrate over the volume, V, of a magnetic flux tube connected to the area on the surface of the earth above which we are measuring the particle deposition, $I(\theta_d, \lambda_d, \lambda_o)$. θ_d and λ_d are the magnetic coordinates of that point on the earth's surface, and λ_o is the magnetic latitude of the detonation site.

The rate at which a radioactive sample decays is given by

$$\frac{dN}{dt} \sim \exp\ (-t/\tau)\ . \tag{2}$$

Only a very short period compared with their lifetime, τ, will have elapsed before fast neutrons would have completely escaped the earth's magnetic field, so that one is justified in making a MacLaurin's series expansion of the exponential and keeping only the first two terms. Recognizing that the neutrons will travel out radially from the detonation area, it can then be shown that

$$N(r, \theta, \lambda) = \frac{N_o}{4\pi\, R^2(r, \theta, \lambda, \lambda_o)\, v\tau} \tag{3}$$

where $N(r, \theta, \lambda)$ is equal to the number of neutrons decaying in a unit volume in the magnetosphere as a function of geocentric distance r, magnetic longitude θ, and magnetic latitude λ. N_o equals the total number of neutrons emitted from the reaction, with average speed, v, and lifetime τ. $R(r, \theta, \lambda, \lambda_o)$ is the radial distance from a blast held on or near the surface of the earth at magnetic latitude λ_o to the point (r, θ, λ) in space. For convenience, zero magnetic longitude has been chosen at the blast site.

No account has been made for absorption of neutrons as they leave the detonation area, so that the simplified expression of Eq. 3 is not valid if the explosion is held very far down in the atmosphere.

Clearly $N(r, \theta, \lambda)$ will be equal to zero in those regions of space shadowed by the earth itself. This point will be covered later when we discuss the limits of integration.

A. Energy Spectrum and Penetration

Because of the masses and energies involved, the decay proton will be injocted into the magnetic field with about the same direction and speed as the parent neutron. The angular distribution of the decay betas will, however, be essentially isotropic in the earth frame of reference and the energy spectrum will be about the same as that of electrons from neutrons decaying at rest. Range-energy curves [UCRL-2426] show that the beta particles from neutron decay can penetrate deeply into the D-region, but protons are prevented from reaching quite as low. The effects of protons will be felt principally above 80 km, and electrons principally below 80 km.

B. Critical Injection Pitch Angle

As a charged particle travels through the magnetosphere, guided along a field line, the pitch angle, $\alpha(\lambda)$, changes with latitude according to the formula,

$$\frac{\sin^2\alpha(\lambda)}{B(\lambda)} = \text{const} \tag{4}$$

where $B(\lambda)$ is the magnetic flux density on the given field line at a latitude, λ, as shown in Figure 2.

In order to obtain a functional dependence of the critical injection pitch angle $\alpha_c(\lambda)$ with latitude, we shall consider $\alpha_c(\lambda)$ as that angle which would result in mirroring at the surface of the earth. This condition implies that

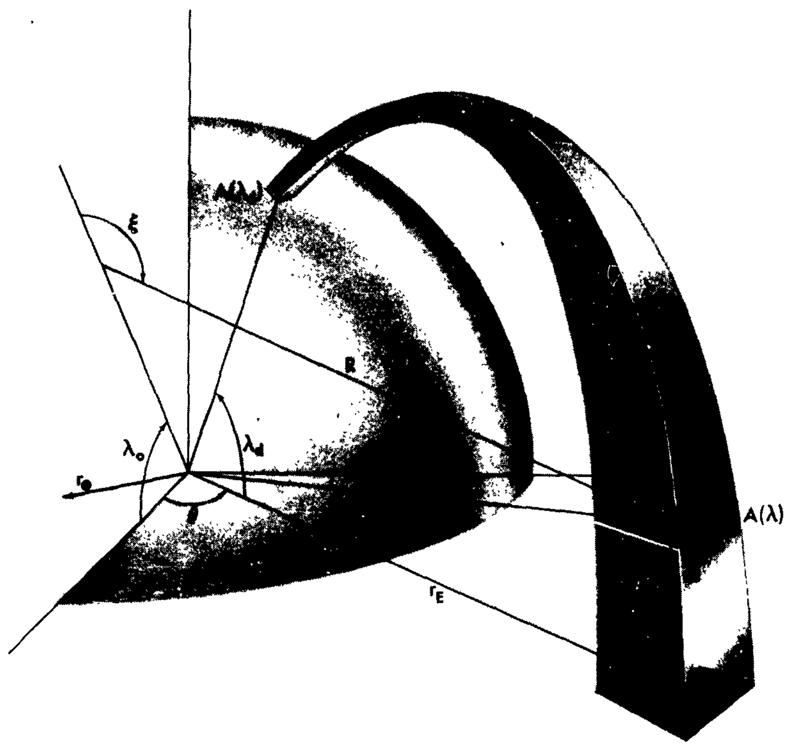

Fig. 2. Coordinate system used in calculation of neutron decay product precipitation.

the critical pitch angle at the surface of the earth, $\alpha_c(\lambda_d)$, is equal to ninety degrees. Hence, in this case, one is able to evaluate the constant in Eq. 4, so that,

$$\frac{\sin^2\alpha_c(\lambda)}{B(\lambda)} = \text{const} = \frac{1}{B(\lambda_d)} , \tag{5}$$

where $B(\lambda_d)$ is the magnetic flux density on the surface of the earth.

Considering that particles are injected isotropically into the magnetosphere (valid only for beta particles), one can calculate that fraction $Y(r)$ of the total which will be injected below the critical angle for immediate deposition in one hemisphere.

It can easily be shown that

$$Y(r) = \left[\frac{1}{2}\right]\left[1 - \cos\alpha_c\right] . \tag{6}$$

The criticality condition specified in Eq. 5 may be used in rewriting Eq. 6 to obtain,

$$Y(r) = \frac{1}{2}\left(1 - \sqrt{1 - B(\lambda)/B(\lambda_d)}\right) . \tag{7}$$

As shown in Appendix I, one may express $B(\lambda)/B(\lambda_d)$ as a function only of λ and λ_d. It then follows that Y may be expressed as a function only of λ and λ_d.

$$Y(r) = Y(\lambda, \lambda_d) =$$

$$\frac{1}{2}\left[1 - (1 - \cos^6\lambda_d \cos^{-6}\lambda\ [1+3\sin^2\lambda]^{1/2}[1+3\sin^2\lambda_d]^{-1/2})\right]. \qquad (8)$$

C. Coordinate Transforms

Since the integration outlined in Eq. 1 will be performed over the volume of a flux tube subtending a small arbitrary area $A(\lambda_d)$ on the surface of the earth, it is useful to express the volume element dv as an elementary volume element of the flux tube itself. As shown in Appendix I,

$$dv = A(\lambda_d)\ \frac{r_\oplus\sqrt{1 + 3\sin^2\lambda_d}}{\cos^8\lambda_d}\ \cos^7\lambda\, d\lambda\ , \qquad (9)$$

where $r_\oplus$ is the radius of the earth.

In addition to this, the $R(r, \theta, \lambda, \lambda_o)$ expressed in Eq. 3, and shown in Figure 2, should be written out explicitly. It can be shown that

$$R^2(r,\theta,\lambda,\lambda_o) = r^2 + r_\oplus^2 - 2r_\oplus r\ (\cos\lambda\ \cos\theta\ \cos\lambda_o + \sin\lambda\ \sin\lambda_o) \quad (10)$$

One may make the r dependence of R implicit in λ_d and the other variables by recognizing that the integration will be carried out along a field line. Using the appropriate substitutions as shown in Appendix I, we obtain

$$R^2(\theta,\lambda,\lambda_o,\lambda_d) = r_\oplus^2\ \sec^4\lambda_d\Big[\cos^4\lambda + \cos^4\lambda_d - 2\cos^2\lambda\ \cos^2\lambda_d \Big(\cos\lambda\ \cos\theta\ \cos\lambda_o + \sin\lambda\ \sin\lambda_o\Big)\Big]. \qquad (11)$$

III. INTEGRAL EXPRESSION

Upon consideration of all the foregoing, and upon substitution of the appropriate expressions, one may obtain from Eq. 1,

$$I(\theta_d, \lambda_d) = \frac{A(\lambda_d)\, N_o \sqrt{1 + 3\sin^2\lambda_d}}{4\pi v\ \tau\ r_\theta \cos^4\lambda_d}$$

$$\int_{\lambda_1}^{\lambda_2} \frac{d\lambda\ \cos^7\lambda \left[\frac{1}{2} - \frac{\cos^6\lambda_d\sqrt{1 + 3\sin^2\lambda}}{2\cos^6\lambda\sqrt{1 + 3\sin^2\lambda_d}}\right]}{\cos^4\lambda_d + \cos^4\lambda - 2\cos^2\lambda_d\cos^2\lambda(\cos\lambda\ \cos\theta\ \cos\lambda_o + \sin\lambda\ \sin\lambda_o)} \tag{12}$$

as the number of betas promptly precipitated into the ionosphere at one end of a field line above an area $A(\lambda_d)$.

This must be, of course, integrated over the appropriate range of latitude, λ_2 to λ_1.

If one had allowed $Y(r)$ to be equal to unity, the resulting expression, $I'(\theta_d, \lambda_d)$,

$$I'(\theta_d, \lambda_d) = \frac{A(\lambda_d)\, N_o \sqrt{1 + 3\sin^2\lambda_d}}{4\pi v\ \tau\ r_\theta \cos^4\lambda_d}$$

$$\int_{\lambda_1}^{\lambda_2} \frac{d\lambda\ \cos^7\lambda \left[1\right]}{\cos^4\lambda_d + \cos^4\lambda - 2\cos^2\lambda_d\cos^2\lambda\ (\cos\lambda\ \cos\theta\ \cos\lambda_o + \sin\lambda\ \sin\lambda_o)} \tag{13}$$

would equal the total number of beta particles or protons injected into a flux tube connected to an area $A(\lambda_d)$ on the surface of the earth. It can be seen that $I' - 2I$ will equal the number of electrons that remain as trapped radiation.

A. Integration Limits

We have chosen as the limits of integration the latitudes of intersection of the field line along which we are integrating with a plane tangent to the earth at the explosion site.

The locus of intersection of the earth's magnetic field lines with a plane tangent to the earth's surface at magnetic longitude zero and magnetic latitude λ_o is defined by the equation

$$\sin\lambda_o \tan\lambda + \cos\lambda_o \cos\theta = \cos^2\lambda_d \sec^3\lambda \ . \tag{14}$$

The two real roots of this equation are the appropriate limits of integration λ_2 and λ_1. The neutron decay density is considered zero on the other side of this plane. This is clearly an approximation which we should discuss in two categories.

a) Explosions at very high altitude

For very high altitude detonations, the shadow plane shown in Figure 1 should be replaced by a shadow cone with resulting change in integration limits. For altitudes small in comparison with the earth's radius, the approximation of a shadow plane instead of a shadow cone is reasonable. The calculation is valid for most high altitude nuclear explosions held thus far.

b) Explosions in the atmosphere

If the explosion is held within the atmosphere, there will be atmospheric absorption of some of the neutrons. This would produce, in effect, an acute shadow cone instead of an obtuse cone or plane. Since no attempt was made to include the accurate absorption term, $A(\xi)$, shown in Eq. 15,

$$A(\xi) = \exp(-\mu x_o \sec \xi), \tag{15}$$

where ξ is the zenith angle, μ is the linear absorption coefficient, and x_o is the residual atmosphere, caution should be applied in interpreting the results of this calculation for explosions held at aircraft altitudes or below.

B. Resumé of Approximations

Although several approximations have been used, they do not seriously limit the validity of the calculation for most applications. It is therefore, useful to list the various approximations.

1) A centered dipole field approximation was used instead of a more correct model of the earth's field.
2) No account of atmospheric absorption was made.
3) A shadow plane instead of a shadow cone was used.
4) A two term MacLaurin series expansion was used for an exponential neutron lifetime term.
5) The fusion portion of the reaction was not considered. Inclusion of this would drastically modify the neutron energy spectrum and number of particles per kiloton yield.

IV. COMPUTATIONS

A computer program was set up to solve for

$$I\ (\theta_d, \lambda_d, \lambda_o) \text{ and } I'(\theta_d, \lambda_d, \lambda_o) \tag{16}$$

for a one kiloton device exploded at values of λ_o equal to 15°, 40°, 45° and 65°. We have chosen these source latitudes since the United States Atomic Energy Commission has announced American high altitude tests [AEC, E-400] at Johnston Island ($\lambda_o \simeq 15°$), and Russian tests [AEC, E-384; AEC, E-394] at Novaya Zemlya ($\lambda_o \simeq 65°$), Semipalatinsk ($\lambda_o \simeq 40°$), and "Central Asia." For lack of more precise information, we have assumed that "Central Asia" is somewhere near Semipalatinsk and have integrated the additional case of $\lambda_o = 45°$.

Our principal uncertainty in evaluating these integrals is in the determination of the number of neutrons leaving a fission area. Semat [1959] lists 2.5 neutrons emitted per fission, of which, presumably one is needed in the chain reaction. Glasstone [1962] lists $(1.5)(10^{23})$ as the number of fissions that occur in a device for each kiloton of fission yield. An additional small error is introduced by assuming that one could represent the complex energy spectrum of bomb-produced neutrons [Watt, 1952] by an average energy of about 1 Mev. Using these numbers, I and I′ have been calculated for a one kT device at each of the four source latitudes. Detailed results of these calculations are tabulated in Appendix II.

In order to give an idea of the geographical extent of these integrals, equivalue contours of I and I′ per kiloton are plotted on normal mercator projections of the earth in Figures 3, 4, 5, 6, 7, 8, 9, and 10, taking into account the difference between geographic and magnetic dipole coordinates.

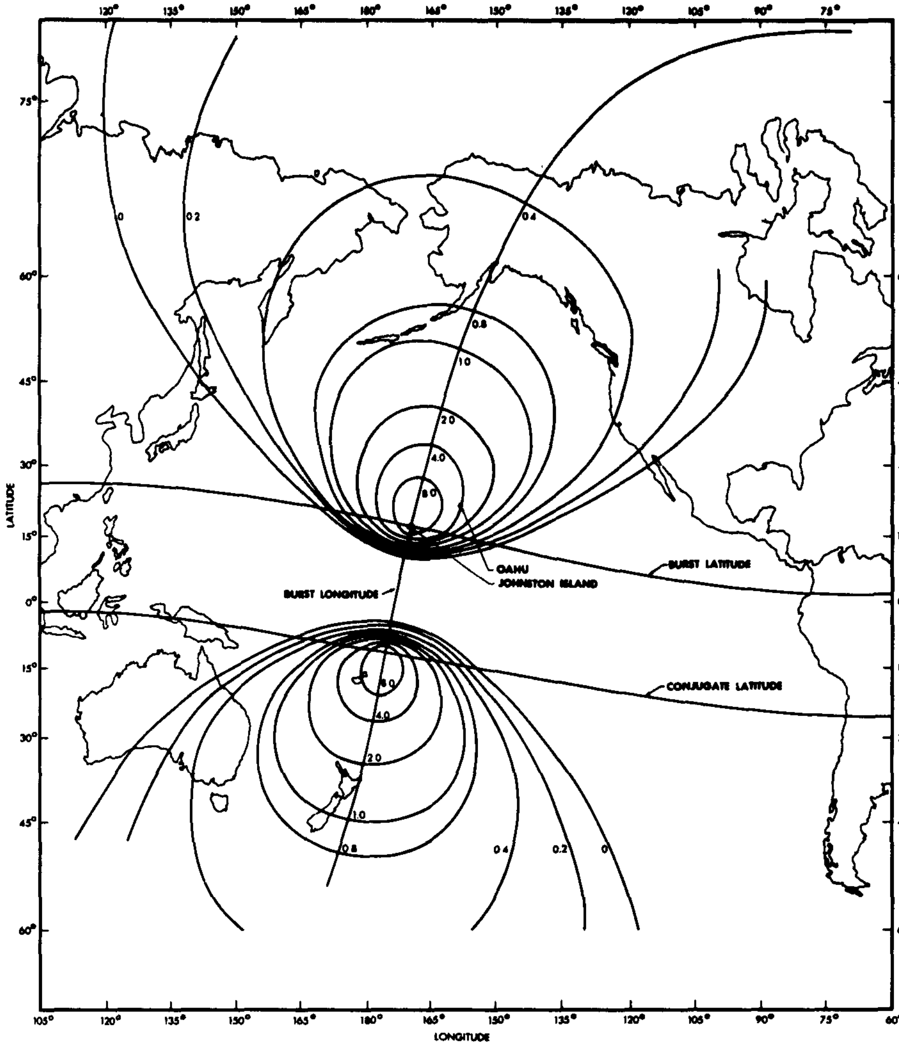

Fig. 3. Contours of prompt beta deposition above one sq. cm. of the earth's surface, $I(\theta_d, \lambda_d)$, due to a one kiloton fission detonation over Johnston Island.

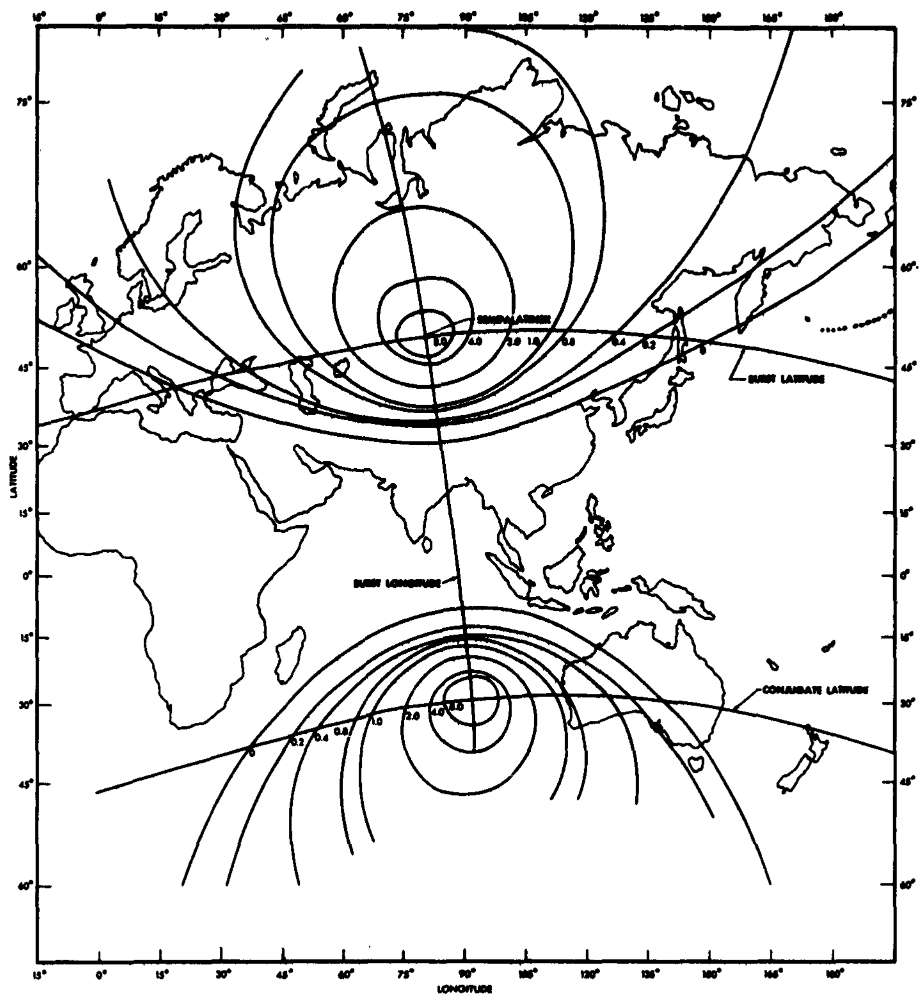

Fig. 4. Contours of prompt beta deposition above one sq. cm. of the earth's surface, $I(\theta_d, \lambda_d)$, due to a one kiloton fission detonation over Semipalatinsk.

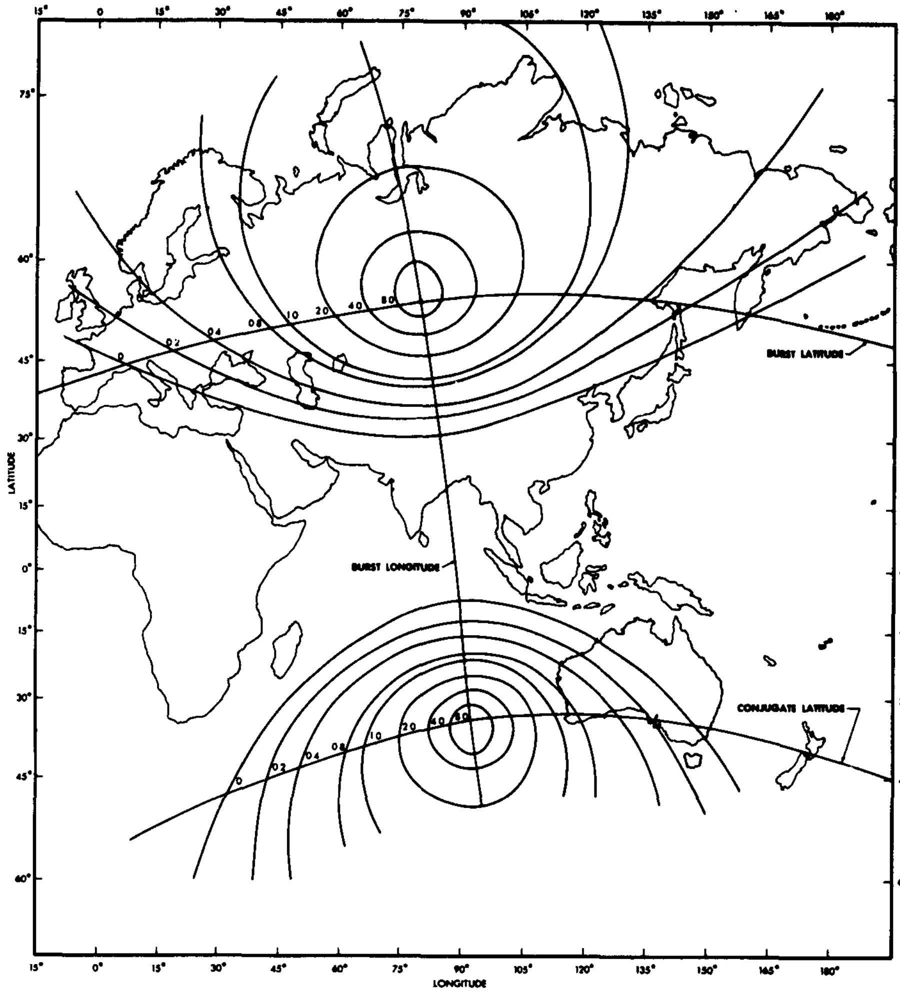

Fig. 5. Contours of prompt beta deposition above one sq. cm. of the earth's surface, $I(\theta_d, \lambda_d)$, due to a one kiloton fission detonation 5° north of Semipalatinsk.

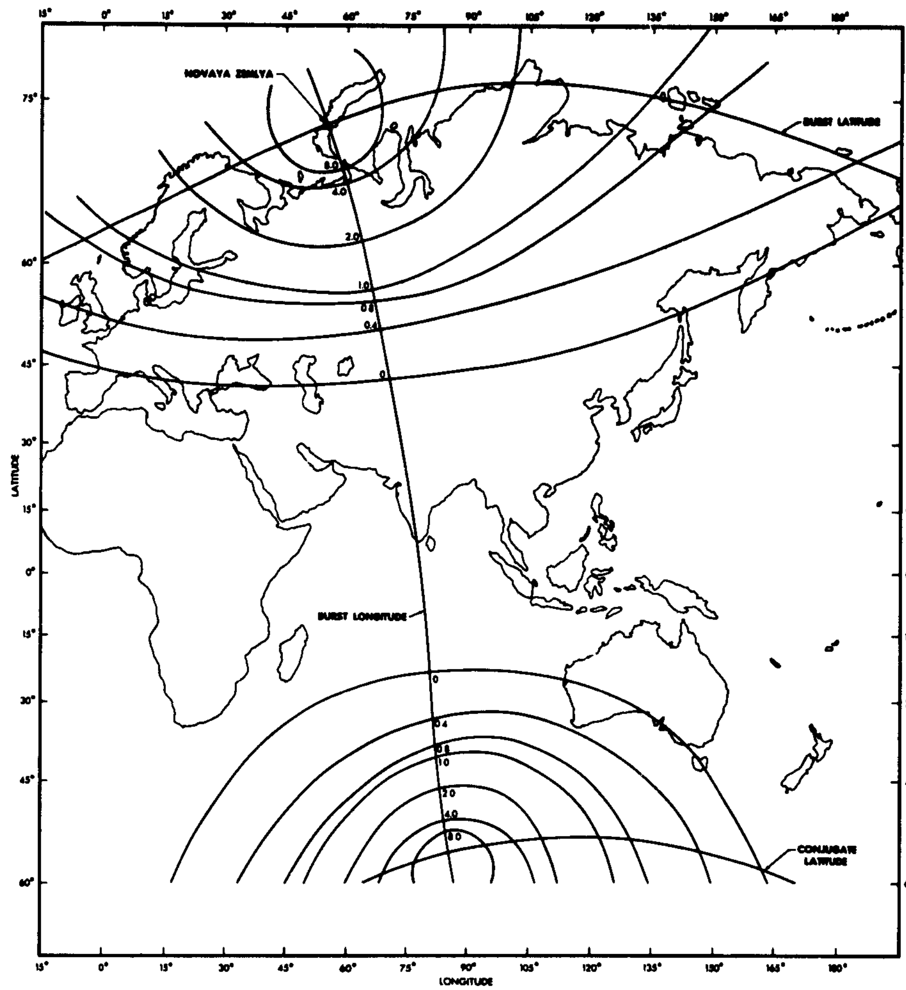

Fig. 6. Contours of prompt beta deposition above one sq. cm. of the earth's surface, $I(\theta_d, \lambda_d)$, due to a one kiloton fission detonation over Novaya Zemlya.

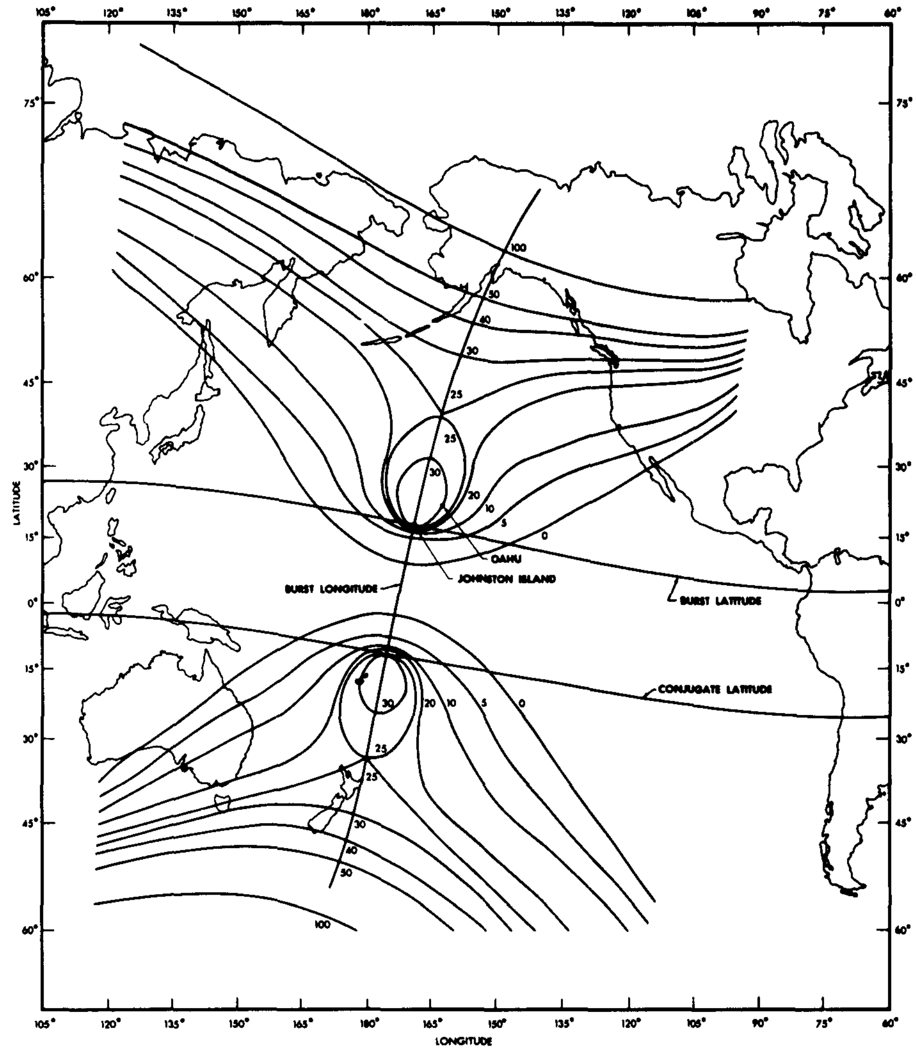

Fig. 7. Contours of decay product production within a flux tube having one sq. cm. area at the earth's surface, $I'(\theta_d, \lambda_d)$, due to a one kiloton fission detonation over Johnston Island.

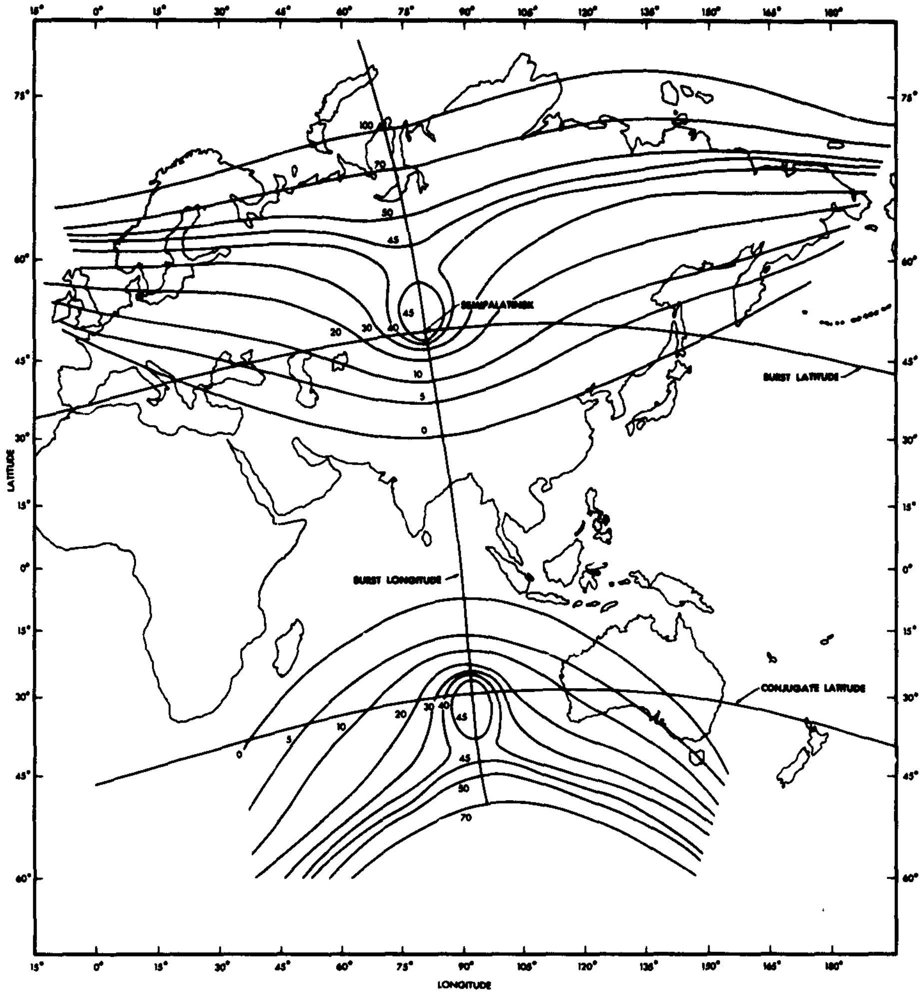

Fig. 8. Contours of decay product production within a flux tube having one sq. cm. area at the earth's surface, $I'(\theta_d, \lambda_d)$, due to a one kiloton fission detonation over Semipalatinsk.

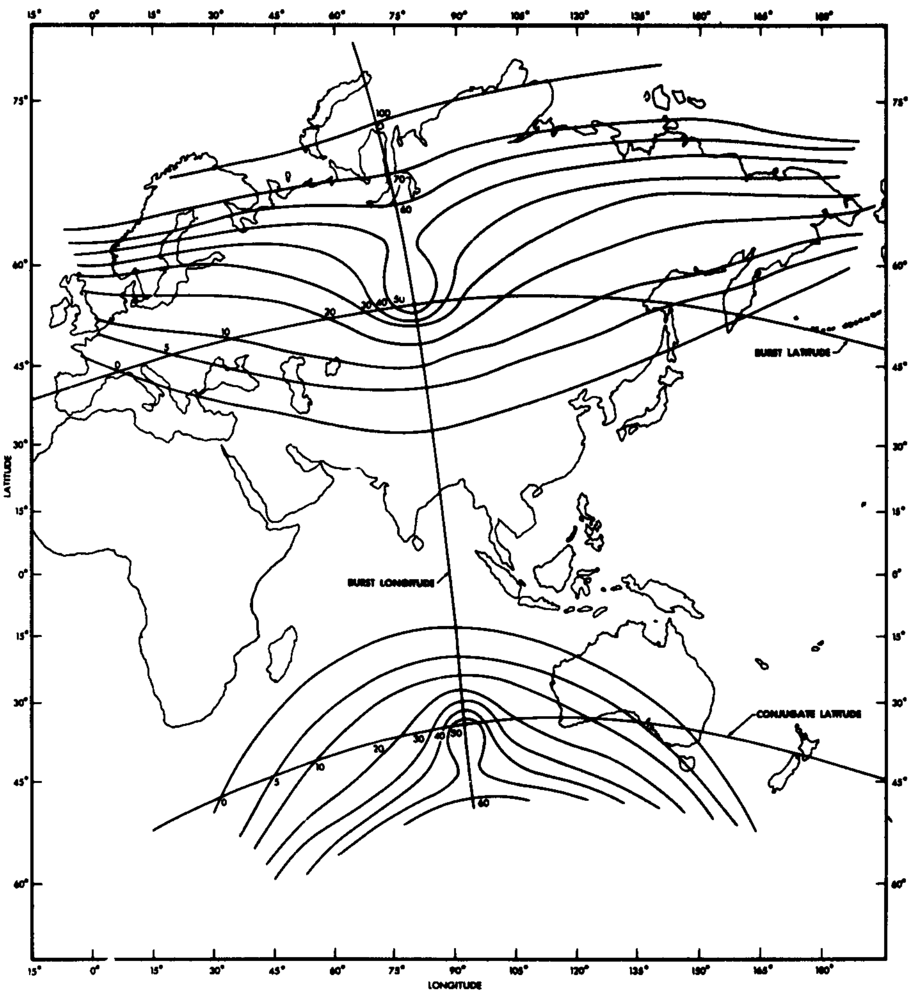

Fig. 9. Contours of decay product production within a flux tube having one sq. cm. area at the earth's surface, $I'(\theta_d, \lambda_d)$, due to a one kiloton fission detonation 5° north of Semipalatinsk.

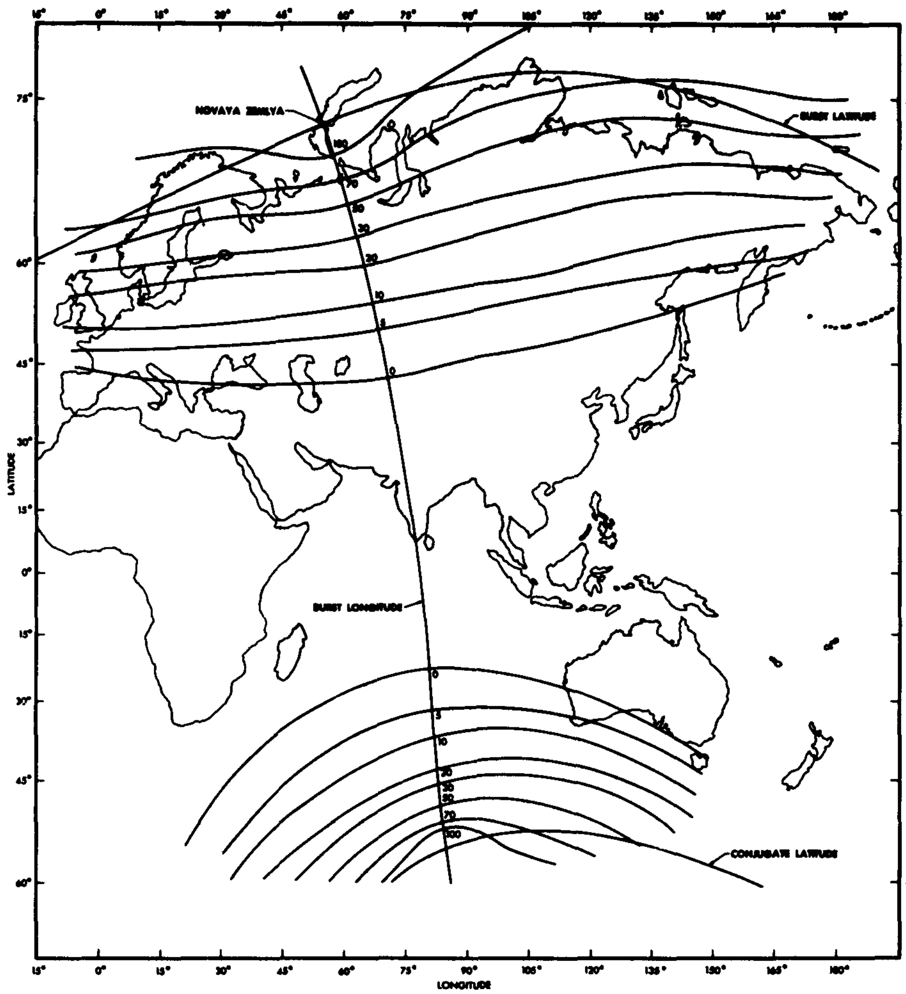

Fig. 10. Contours of decay product production within a flux tube having one sq. cm. area at the earth's surface, $I'(\theta_d, \lambda_d)$, due to a one kiloton fission detonation over Novaya Zemlya.

V. RESULTS

A. Prompt Beta Precipitation

The contours shown in Figures 3, 4, 5, and 6 are directly equal to the number of betas precipitated on the first pass into the ionosphere above one square centimeter of the earth's surface for each kiloton of fission. Taking 350 kev as the average energy of the neutron decay betas, and 35 ev [Chamberlain, 1961] as the average amount of energy necessary to create an ion pair in the atmosphere, one simply needs to multiply the contour values of I per kiloton by 10^4 to obtain the number of ion pairs formed in a column one square centimeter in cross section above the surface of the earth for each kiloton of fission.

Differential range-energy curves [UCRL-2426] have been used to determine the profile of ionization produced in the atmosphere by these beta particles, and the resultant profile is plotted in Figure 11. From this curve, it can be seen that about half the energy is dissipated in a layer about 5 kilometers thick around an altitude of 68 km. A more accurate profile including the effect of field line inclination and particle gyration would raise this layer somewhat and shrink it in thickness. Since half of the excess ionization is formed in a layer approximately five kilometers thick, one may simply multiply the contour values of Figures 3, 4, 5, and

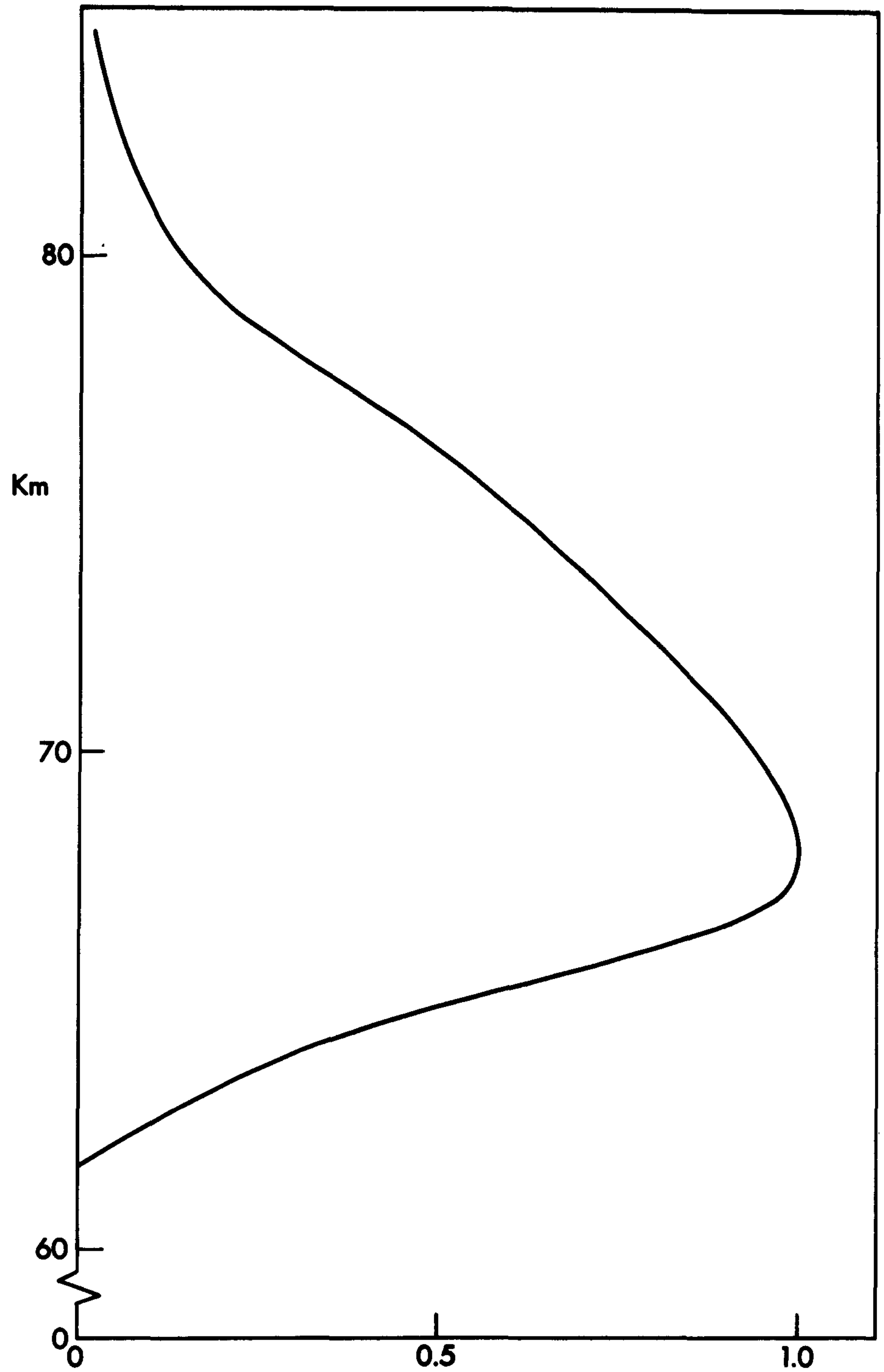

Fig. 11. Energy loss profile of neutron decay betas in the ionosphere. The horizontal scale is in arbitrary units.

6 by 10^{-2} to obtain an estimate of the additional electron density created deep in the D-region due to a one kiloton fission explosion.

As an example of this, one can see from the contours of Figure 3 that one megaton of fission detonated over Johnston Island would result in the very sudden creation of $(4)(10^7)$ ion pairs in a one square centimeter column over Honolulu with an easily-detectable excess density of 40 pairs per cubic centimeter injected well below the normal nightime level of the D-region. On the other hand, since 100 kt of fission exploded over Johnston Island would create only 0.5 ion pairs per cubic centimeter over the western part of the United States, it would be very difficult to detect this increase by VLF techniques.

B. Prompt Proton Precipitation

Protons are not produced isotropically in the earth frame by neutrons travelling radially outward from a blast and no attempt was made in the integral to introduce a non-isotropic injection pitch angle distribution. From geometrical considerations, it would appear that fewer protons than electrons would be precipitated on the first bounce. In addition to this, their penetration and ionizing ability are different from electrons. A 2 Mev proton would penetrate only to about 80 km, but produce $(6)(10^4)$ ion pairs.

Although protons above 10 Mev are capable of penetrating as deeply as the betas and producing many more ion pairs, there are so few of them [Watt, 1952], that they do not appear to be an important source of ionization in the D-region. It is to be emphasized that we have considered only the neutrons from a fission reaction.

C. <u>Trapped Radiation</u>

The contours of I' per kiloton shown in Figures 7, 8, 9, and 10 show the number of protons or electrons injected into the magnetosphere in a flux tube connected to one square centimeter on different portions of the earth's surface by one kiloton of fission exploded at the various source latitudes. One must subtract 2I from I' to eliminate those particles lost in both hemispheres on the first penetration to obtain the component that may be trapped for a measurable period of time. These trapped particles will drift around the world and lose their initial longitudinal anisotropy. Taking into consideration the divergence of the flux tube from the earth's surface out to the equatorial plane, and assuming longitudinal isotropy, one can calculate the number, $P(\lambda)$, of electrons or protons in a flux tube one centimeter square in area at the equatorial plane and connected to the earth at latitude λ due to neutron decay from a fission explosion. $P(\lambda)$ is tabulated in the third column of Table I for a one kiloton device exploded at Johnston Island.

If one were to divide $P(\lambda)$ by the time necessary for the trapped particle to bounce from one extreme to the other in latitude, one would obtain the omnidirectional flux of particles per square centimeter per second in the equatorial plane at various geocentric distances. The major contribution to the flux would be from electrons, since the average speed of the protons is considerably smaller. Liemohn [1961] has demonstrated that the bounce period for electrons is not strongly dependent on the mirror latitude, but does depend on the McIlwain L value [McIlwain, 1961] of the shell, and on the electron energy. Assuming an average energy of 350 kev for the electrons, one can compute the omnidirectional flux J(L) of electrons at various L values due to neutron decay.

J(L) for a one kiloton explosion at Johnston Island is shown in the fourth column of Table I.

TABLE I

Trapped Betas due to neutron decay in a flux tube subtending one square centimeter in the equatorial plane per kiloton of fission above Johnston Island ($\lambda_o = 15°$).

λ	L	$P(\lambda)$ $N_e cm^{-2} kT^{-1}$	$J(L)$ $N_e cm^{-2} sec^{-1} kT^{-1}$
10°	1.03	0.17	12.
15°	1.07	--	--
20°	1.13	2.7	170.
25°	1.22	1.4	81.
30°	1.33	0.93	50.
35°	1.49	0.73	35.
40°	1.70	0.57	24.
45°	2.00	0.44	16.
50°	2.42	0.34	10.
55°	3.04	0.26	6.1
60°	4.00	0.19	3.5
65°	5.60	0.13	1.7

VI. COMPARISON WITH EXPERIMENT

A. V.L.F. Experiments

Detailed studies have been made of changes in the phase and amplitude recordings of VLF stations during the large American high altitude test of July 9, 1962 [Zmuda, et. al., 1963; Sechrist, 1962] and the Russian and American tests held later in the same year [Willard and Kenney, 1963]. The phase and amplitude changes are interpreted as due to changing ionospheric conditions occasioned by the nuclear tests.

Two types of effects are noticed on the recordings. One is a very prompt effect, not noticed on all the records, in which the signal characteristics change quickly and also recover quickly. Onset time is less than one second, and recovery is well on its way in a few tens of seconds. The onset of the second change in signal characteristics is delayed a few minutes, and recovery takes much longer.

B. Impulsive Ionization in the D-Region

The immediate effect on VLF propagation characteristics at the time of a nuclear blast [Zmuda, et. al., 1963; Willard and Kenney, 1963; Sechrist, 1962] has been explained by the prompt precipitation into the ionosphere of the decay products of fission neutrons. The geographical effects noted by these authors agree with the contours shown in Figure 3. The quantity of ionization produced is, however, weaker than expected and is probably not sufficient to explain the magnitude of the effects. Although the approximations made in these calculations certainly introduce some error, it is felt that they are accurate within an order of magnitude. Although weapon systems utilize both fusion and fission reactions [Lapp, 1961], we have considered only fission neutrons. If one were to consider also the fusion portion of the reaction [Rose and Clark, 1961], a greatly modified neutron spectrum would result. As shown in the section dealing with prompt proton precipitation, the D-region effects would be greatly enhanced by additional ionization from penetrating protons if neutrons were produced in quantity with energies above 10 Mev.

C. Short Lived Trapped Radiation

It would be difficult to distinguish the small component of trapped radiation due to neutron decay by direct satellite observation when their detectors would be completely swamped by the more profuse and energetic component due to those betas injected directly from the explosion area. The authors feel, however, that evidence exists for indirect detection of this component. The Seismological Institute at Uppsala [Båth, 1963] announced the detonation of a 26 megaton nuclear explosion at Novaya Zemlya at

0906 UT, on October 22, 1962. R. Meuse [1962] has furnished the authors with a record of WWVL (Seattle to Boulder, 20.0 kc) phase reception which can be interpreted as showing an increase in ionization in the D-region along the Seattle-Boulder propagation path starting about 0935 UT, and reaching a maximum about 1003 UT on the same day.

Radiation injected into the magnetosphere from the nuclear detonation, not lost on the first north-south bounce, but mirroring at low altitude, will undergo scatterings and subsequently be lost into the ionosphere as it drifts eastward around the world. Betas produced in the fireball cannot reach the Seattle-Boulder path because this is at a lower L value than Novaya Zemlya. Beta particles from the neutron-decay source, are, however, produced in quantity in magnetic shells at the same latitude as the transmission path, but not at the same longitude. Drift times for geomagnetically trapped betas having a neutron-decay spectrum fit the necessary time delays quite well. Even though the October 22, 1962 explosion was not conducted above the atmosphere, the yield of the explosion was large enough to allow a sufficient quantity of neutrons to escape from the atmosphere and decay in the magnetosphere. Since there was no appreciable amount of solar activity which could act as a source for this excess ionization, the authors feel that the VLF effects are due to trapped radiation from the neutron-decay source.

D. Long-Lived Trapped Radiation

Satellite counting rates before and after the July 9, 1962 nuclear detonation at Johnston Island [O'Brien, et. al., 1962; Brown, et. al., 1963] show that even the normal background trapped radiation exceeds that which can be considered from our calculations as due to neutron decay products. The normal trapped radiation has large time variations and is softer than the fission beta spectrum, so that even the softer component of trapped radiation detected by satellites at large L values cannot be interpreted as being due to the neutron decay source.

Cumulative effects of a whole series of tests may possibly give a measurable increase at large L values due to the neutron-decay mechanism but even this is unlikely.

VII. SUMMARY

The neutron-decay theory has been analyzed to determine the quantitative effect that a nuclear explosion may have on the ionosphere immediately after a nuclear detonation at regions remote from the blast site. It can be concluded that the fission neutron source is useful in explaining the morphology of nuclear-associated VLF effects, although the amount of ionization produced promptly in the D-region may be insufficient to account for the magnitude of these effects. If one were to consider the fusion portion of the device, the resultant neutron energy spectrum would be greatly modified. Fast protons coming from these energetic neutrons could easily increase the D-layer perturbations one or two orders of magnitude. Evidence has also been shown for the indirect detection of short-lived trapped radiation from the neutron-decay source.

Appendix 1. The Geomagnetic Dipole

Since we have assumed that the earth's magnetic field may be approximated by a centered dipole, it will be useful to review some of the characteristics thereof.

The equation of a dipole field line as shown in Figure 2 is

$$r = r_E \cos^2\lambda \tag{1}$$

where r is the geocentric distance to the field line, r_E is the geocentric distance to the point where the field line crosses the magnetic equator, and λ is the magnetic latitude of the point. The scalar magnetic flux density $B(r, \lambda)$ is given by

$$B(r, \lambda) = br^{-3}\left[1 + 3\sin^2\lambda\right]^{1/2} \tag{2}$$

where b is the dipole moment of the earth. One may substitute Eq. 1 in Eq. 2 to arrive at

$$B(r,\lambda) = br_E^{-3}\cos^{-6}\lambda\left[1 + 3\sin^2\lambda\right]^{1/2} = B_E\cos^{-6}\lambda\left[1 + 3\sin^2\lambda\right]^{1/2}, \tag{3}$$

where B_E is the magnetic flux density at r_E.

Any small area on the surface of the earth located at magnetic latitude λ_d is connected to a flux tube of constant longitude, θ, which extends out into space as shown in Figure

2. Although the cross-sectional area of this tube changes, the magnetic flux density also changes, so that flux is conserved. Thus, for a given tube, one may write

$$B(\lambda)A(\lambda) = B(\lambda_d)A(\lambda_d) = B_E A_E = \text{const} . \tag{4}$$

An infinitesimal volume element of this flux tube, dv, may be expressed as a product of the cross-sectional area of the tube, $A(\lambda)$, and an infinitesimal length along the tube, dl.

$$dv = A(\lambda)dl \tag{5}$$

Since the magnetic field line is conveniently expressed in Eq. 1 in spherical coordinates, it is possible to use the differential equation

$$dl = \left[(dr/d\lambda)^2 + r^2\right]^{1/2} d\lambda \tag{6}$$

to arrive at a more useful form for dl and dv.

$$dl = r_E \cos\lambda \left[1 + 3\sin^2\lambda\right]^{1/2} d\lambda, \text{ and,} \tag{7}$$

$$dv = A_E B_E B(\lambda)^{-1} r_E \cos\lambda \left[1 + 3\sin^2\lambda\right]^{1/2} d\lambda , \tag{8}$$

or, from Eq. 3,

$$dv = A_E \cos^7\lambda \; r_E d\lambda . \tag{9}$$

In the above expression for dv, one notes that the equatorial values of geocentric distance, r_E, and cross-sectional area, A_E, are used. One may replace r_E in terms of the earth's radius, $r_\oplus$, by taking the particular case of Eq. 1 where the field line intersects the earth's surface at latitude λ_d,

$$r_\oplus = r_E \cos^2\lambda_d \ . \tag{10}$$

One may also use Eqs. 3 and 4 to express A_E in terms of $A(\lambda_d)$,

$$A_E = A(\lambda_d)\ \cos^{-6}\lambda_d\left[1 + 3\ \sin^2\lambda_d\right]^{1/2} \ . \tag{11}$$

Substitution of the expressions of Eqs. 10 and 11 in Eq. 9 yields the form for dv which shall prove useful,

$$dv = r_\oplus A(\lambda_d)\ \cos^{-8}\lambda_d \cos^7\lambda\left[1 + 3\ \sin^2\lambda_d\right]^{1/2} d\lambda \ . \tag{12}$$

Appendix 2. Tabulations of I and I′ per Kiloton for Four Source Latitudes

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	4.750E-01
60.0	0.0	5.977E-01
55.0	0.0	7.567E-01
50.0	0.0	9.736E-01
45.0	0.0	1.286E-00
40.0	0.0	1.769E-00
35.0	0.0	2.580E-00
30.0	0.0	4.119E-00
25.0	0.0	7.679E-00
20.0	0.0	2.027E+01
15.0	0.0	7.505E+03
10.0	0.0	2.478E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	4.720E-01
60.0	5.0	5.926E-01
55.0	5.0	7.478E-01
50.0	5.0	9.573E-01
45.0	5.0	1.254E-00
40.0	5.0	1.699E-00
35.0	5.0	2.406E-00
30.0	5.0	3.589E-00
25.0	5.0	5.562E-00
20.0	5.0	7.828E-00
15.0	5.0	6.037E-00
10.0	5.0	1.226E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	4.630E-01
60.0	10.0	5.776E-01
55.0	10.0	7.221E-01
50.0	10.0	9.111E-01
45.0	10.0	1.166E-00
40.0	10.0	1.518E-00
35.0	10.0	2.000E-00
30.0	10.0	2.605E-00
25.0	10.0	3.150E-00
20.0	10.0	3.124E-00
15.0	10.0	2.064E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	4.486E-01
60.0	15.0	5.539E-01
55.0	15.0	6.822E-01
50.0	15.0	8.419E-01
45.0	15.0	1.041E-00
40.0	15.0	1.285E-00
35.0	15.0	1.555E-00
30.0	15.0	1.784E-00
25.0	15.0	1.829E-00
20.0	15.0	1.526E-00
15.0	15.0	7.164E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	4.293E-01
60.0	20.0	5.229E-01
55.0	20.0	6.318E-01
50.0	20.0	7.585E-01
45.0	20.0	9.016E-01
40.0	20.0	1.049E-00
35.0	20.0	1.171E-00
30.0	20.0	1.210E-00
25.0	20.0	1.094E-00
20.0	20.0	7.499E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	4.060E-01
60.0	25.0	4.865E-01
55.0	25.0	5.747E-01
50.0	25.0	6.687E-01
45.0	25.0	7.616E-01
40.0	25.0	8.369E-01
35.0	25.0	8.668E-01
30.0	25.0	8.149E-01
25.0	25.0	6.399E-01
20.0	25.0	1.896E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	3.796E-01
60.0	30.0	4.463E-01
55.0	30.0	5.142E-01
50.0	30.0	5.787E-01
45.0	30.0	6.306E-01
40.0	30.0	6.545E-01
35.0	30.0	6.295E-01
30.0	30.0	5.310E-01
25.0	30.0	3.089E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	3.508E-01
60.0	35.0	4.040E-01
55.0	35.0	4.530E-01
50.0	35.0	4.922E-01
45.0	35.0	5.124E-01
40.0	35.0	5.008E-01
35.0	35.0	4.418E-01
30.0	35.0	3.097E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	3.205E-01
60.0	40.0	3.608E-01
55.0	40.0	3.929E-01
50.0	40.0	4.111E-01
45.0	40.0	4.072E-01
40.0	40.0	3.707E-01
35.0	40.0	2.861E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	2.891E-01
60.0	45.0	3.175E-01
55.0	45.0	3.349E-01
50.0	45.0	3.359E-01
45.0	45.0	3.134E-01
40.0	45.0	2.570E-01
35.0	45.0	1.368E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	2.572E-01
60.0	50.0	2.748E-01
55.0	50.0	2.794E-01
50.0	50.0	2.662E-01
45.0	50.0	2.280E-01
40.0	50.0	1.485E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	2.252E-01
60.0	55.0	2.328E-01
55.0	55.0	2.263E-01
50.0	55.0	2.004E-01
45.0	55.0	1.451E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	1.930E-01
60.0	60.0	1.916E-01
55.0	60.0	1.746E-01
50.0	60.0	1.353E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	1.769E-01
60.0	62.5	1.711E-01
55.0	62.5	1.489E-01
50.0	62.5	1.002E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	1.607E-01
60.0	65.0	1.505E-01
55.0	65.0	1.225E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	67.5	1.445E-01
60.0	67.5	1.297E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	1.280E-01
60.0	70.0	1.082E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	1.112E-01
60.0	72.5	8.534E-02

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	1.055E-00
60.0	0.0	1.490E-00
55.0	0.0	2.259E-00
50.0	0.0	3.921E-00
45.0	0.0	9.449E-00
40.0	0.0	5.826E+04
35.0	0.0	4.370E-00
30.0	0.0	1.546E-00
25.0	0.0	5.213E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	1.042E-00
60.0	5.0	1.458E-00
55.0	5.0	2.165E-00
50.0	5.0	3.543E-00
45.0	5.0	6.580E-00
40.0	5.0	8.446E-00
35.0	5.0	3.394E-00
30.0	5.0	1.401E-00
25.0	5.0	4.704E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	1.006E-00
60.0	10.0	1.370E-00
55.0	10.0	1.929E-00
50.0	10.0	2.784E-00
45.0	10.0	3.769E-00
40.0	10.0	3.605E-00
35.0	10.0	2.182E-00
30.0	10.0	1.094E-00
25.0	10.0	3.330E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	9.501E-01
60.0	15.0	1.247E-00
55.0	15.0	1.640E-00
50.0	15.0	2.091E-00
45.0	15.0	2.368E-00
40.0	15.0	2.103E-00
35.0	15.0	1.436E-00
30.0	15.0	7.835E-01
25.0	15.0	7.352E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	8.816E-01
60.0	20.0	1.108E-00
55.0	20.0	1.362E-00
50.0	20.0	1.576E-00
45.0	20.0	1.616E-00
40.0	20.0	1.386E-00
35.0	20.0	9.801E-01
30.0	20.0	5.345E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	8.068E-01
60.0	25.0	9.708E-01
55.0	25.0	1.122E-00
50.0	25.0	1.208E-00
45.0	25.0	1.164E-00
40.0	25.0	9.706E-01
35.0	25.0	6.783E-01
30.0	25.0	3.215E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	7.306E-01
60.0	30.0	8.428E-01
55.0	30.0	9.251E-01
50.0	30.0	9.422E-01
45.0	30.0	8.661E-01
40.0	30.0	6.987E-01
35.0	30.0	4.632E-01
30.0	30.0	8.310E-02

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	6.565E-01
60.0	35.0	7.280E-01
55.0	35.0	7.639E-01
50.0	35.0	7.434E-01
45.0	35.0	6.557E-01
40.0	35.0	5.052E-01
35.0	35.0	2.934E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	5.866E-01
60.0	40.0	6.270E-01
55.0	40.0	6.321E-01
50.0	40.0	5.906E-01
45.0	40.0	4.985E-01
40.0	40.0	3.571E-01
35.0	40.0	1.290E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	5.217E-01
60.0	45.0	5.388E-01
55.0	45.0	5.234E-01
50.0	45.0	4.694E-01
45.0	45.0	3.749E-01
40.0	45.0	2.330E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	4.622E-01
60.0	50.0	4.618E-01
55.0	50.0	4.323E-01
50.0	50.0	3.702E-01
45.0	50.0	2.723E-01
40.0	50.0	1.059E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	4.080E-01
60.0	55.0	3.943E-01
55.0	55.0	3.546E-01
50.0	55.0	2.861E-01
45.0	55.0	1.795E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	3.587E-01
60.0	60.0	3.346E-01
55.0	60.0	2.870E-01
50.0	60.0	2.113E-01
45.0	60.0	7.330E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	3.357E-01
60.0	62.5	3.072E-01
55.0	62.5	2.559E-01
50.0	62.5	1.753E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	3.138E-01
60.0	65.0	2.812E-01
55.0	65.0	2.263E-01
50.0	65.0	1.385E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	67.5	2.928E-01
60.0	67.5	2.564E-01
55.0	67.5	1.975E-01
50.0	67.5	9.788E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	2.726E-01
60.0	70.0	2.326E-01
55.0	70.0	1.691E-01
50.0	70.0	3.928E-02

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	2.533E-01
60.0	72.5	2.095E-01
55.0	72.5	1.402E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	75.0	2.346E-01
60.0	75.0	1.870E-01
55.0	75.0	1.095E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	77.5	2.164E-01
60.0	77.5	1.647E-01
55.0	77.5	7.333E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	80.0	1.987E-01
60.0	80.0	1.421E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	82.5	1.814E-01
60.0	82.5	1.186E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(YD/YR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	1.400E-00
60.0	0.0	2.122E-00
55.0	0.0	3.674E-00
50.0	0.0	8.830E-00
45.0	0.0	3.239E+05
40.0	0.0	4.570E-00
35.0	0.0	1.692E-00
30.0	0.0	7.176E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	1.378E-00
60.0	5.0	2.054E-00
55.0	5.0	3.392E-00
50.0	5.0	6.553E-00
45.0	5.0	9.311E-00
40.0	5.0	3.649E-00
35.0	5.0	1.557E-00
30.0	5.0	6.753E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	1.314E-00
60.0	10.0	1.875E-00
55.0	10.0	2.783E-00
50.0	10.0	3.990E-00
45.0	10.0	4.020E-00
40.0	10.0	2.430E-00
35.0	10.0	1.264E-00
30.0	10.0	5.665E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	1.221E-00
60.0	15.0	1.644E-00
55.0	15.0	2.176E-00
50.0	15.0	2.590E-00
45.0	15.0	2.380E-00
40.0	15.0	1.649E-00
35.0	15.0	9.632E-01
30.0	15.0	4.244E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	1.112E-00
60.0	20.0	1.407E-00
55.0	20.0	1.694E-00
50.0	20.0	1.808E-00
45.0	20.0	1.598E-00
40.0	20.0	1.165E-00
35.0	20.0	7.121E-01
30.0	20.0	2.668E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	9.991E-01
60.0	25.0	1.193E-00
55.0	25.0	1.333E-00
50.0	25.0	1.330E-00
45.0	25.0	1.146E-00
40.0	25.0	8.454E-01
35.0	25.0	5.116E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	8.893E-01
60.0	30.0	1.008E-00
55.0	30.0	1.064E-00
50.0	30.0	1.013E-00
45.0	30.0	8.525E-01
40.0	30.0	6.206E-01
35.0	30.0	3.470E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	7.872E-01
60.0	35.0	8.537E-01
55.0	35.0	8.603E-01
50.0	35.0	7.891E-01
45.0	35.0	6.461E-01
40.0	35.0	4.524E-01
35.0	35.0	1.973E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	6.948E-01
60.0	40.0	7.242E-01
55.0	40.0	7.022E-01
50.0	40.0	6.226E-01
45.0	40.0	4.921E-01
40.0	40.0	3.131E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	6.122E-01
60.0	45.0	6.159E-01
55.0	45.0	5.767E-01
50.0	45.0	4.936E-01
45.0	45.0	3.708E-01
40.0	45.0	1.996E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	5.339E-01
60.0	50.0	5.246E-01
55.0	50.0	4.748E-01
50.0	50.0	3.899E-01
45.0	50.0	2.696E-01
40.0	50.0	5.326E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	4.740E-01
60.0	55.0	4.468E-01
55.0	55.0	3.899E-01
50.0	55.0	3.031E-01
45.0	55.0	1.775E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	4.163E-01
60.0	60.0	3.797E-01
55.0	60.0	3.175E-01
50.0	60.0	2.270E-01
45.0	60.0	6.947E-02

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	3.899E-01
60.0	62.5	3.495E-01
55.0	62.5	2.848E-01
50.0	62.5	1.909E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	3.650E-01
60.0	65.0	3.211E-01
55.0	65.0	2.539E-01
50.0	65.0	1.546E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	67.5	3.413E-01
60.0	67.5	2.943E-01
55.0	67.5	2.243E-01
50.0	67.5	1.160E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	3.189E-01
60.0	70.0	2.689E-01
55.0	70.0	1.956E-01
50.0	70.0	6.860E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	2.976E-01
60.0	72.5	2.446E-01
55.0	72.5	1.672E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	75.0	2.772E-01
60.0	75.0	2.212E-01
55.0	75.0	1.382E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	77.5	2.577E-01
60.0	77.5	1.985E-01
55.0	77.5	1.070E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	80.0	2.389E-01
60.0	80.0	1.762E-01
55.0	80.0	6.961E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	82.5	2.208E-01
60.0	82.5	1.538E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	85.0	2.031E-01
60.0	85.0	1.309E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	1.769E+05
60.0	0.0	5.295E-00
55.0	0.0	2.136E-00
50.0	0.0	1.139E-00
45.0	0.0	6.335E-01
40.0	0.0	2.822E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	1.679E+01
60.0	5.0	4.774E-00
55.0	5.0	2.063E-00
50.0	5.0	1.116E-00
45.0	5.0	6.233E-01
40.0	5.0	2.758E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	7.501E-00
60.0	10.0	3.779E-00
55.0	10.0	1.876E-00
50.0	10.0	1.053E-00
45.0	10.0	5.944E-01
40.0	10.0	2.570E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	4.670E-00
60.0	15.0	2.908E-00
55.0	15.0	1.639E-00
50.0	15.0	9.634E-01
45.0	15.0	5.507E-01
40.0	15.0	2.266E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	3.282E-00
60.0	20.0	2.268E-00
55.0	20.0	1.404E-00
50.0	20.0	8.612E-01
45.0	20.0	4.971E-01
40.0	20.0	1.849E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	2.473E-00
60.0	25.0	1.809E-00
55.0	25.0	1.194E-00
50.0	25.0	7.575E-01
45.0	25.0	4.382E-01
40.0	25.0	1.291E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	1.950E-00
60.0	30.0	1.473E-00
55.0	30.0	1.014E-00
50.0	30.0	6.589E-01
45.0	30.0	3.773E-01
40.0	30.0	1.676E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	1.587E-00
60.0	35.0	1.222E-00
55.0	35.0	8.641E-01
50.0	35.0	5.684E-01
45.0	35.0	3.163E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	1.322E-00
60.0	40.0	1.028E-00
55.0	40.0	7.383E-01
50.0	40.0	4.866E-01
45.0	40.0	2.557E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	1.121E-00
60.0	45.0	8.751E-01
55.0	45.0	6.326E-01
50.0	45.0	4.132E-01
45.0	45.0	1.940E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	9.635E-01
60.0	50.0	7.518E-01
55.0	50.0	5.430E-01
50.0	50.0	3.468E-01
45.0	50.0	1.260E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	8.370E-01
60.0	55.0	6.505E-01
55.0	55.0	4.662E-01
50.0	55.0	2.861E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	7.335E-01
60.0	60.0	5.660E-01
55.0	60.0	3.996E-01
50.0	60.0	2.292E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	6.886E-01
60.0	62.5	5.288E-01
55.0	62.5	3.693E-01
50.0	62.5	2.014E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	6.475E-01
60.0	65.0	4.944E-01
55.0	65.0	3.409E-01
50.0	65.0	1.734E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	67.5	6.097E-01
60.0	67.5	4.625E-01
55.0	67.5	3.139E-01
50.0	67.5	1.445E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 0.5(1.0-SQRF(1.0-(VD/VR)))

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	5.749E-01
60.0	70.0	4.328E-01
55.0	70.0	2.882E-01
50.0	70.0	1.131E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	5.427E-01
60.0	72.5	4.051E-01
55.0	72.5	2.637E-01
50.0	72.5	7.543E-02

LATITUDE	LONGITUDE	DENSITY/KT
65.0	75.0	5.128E-01
60.0	75.0	3.791E-01
55.0	75.0	2.400E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	77.5	4.850E-01
60.0	77.5	3.548E-01
55.0	77.5	2.170E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	80.0	4.592E-01
60.0	80.0	3.318E-01
55.0	80.0	1.944E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	82.5	4.350E-01
60.0	82.5	3.100E-01
55.0	82.5	1.719E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	85.0	4.123E-01
60.0	85.0	2.893E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	1.228E+02
60.0	0.0	7.067E+01
55.0	0.0	4.687E+01
50.0	0.0	3.485E+01
45.0	0.0	2.861E+01
40.0	0.0	2.581E+01
35.0	0.0	2.569E+01
30.0	0.0	2.880E+01
25.0	0.0	3.828E+01
20.0	0.0	7.167E+01
15.0	0.0	1.507E+04
10.0	0.0	6.742E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	1.225E+02
60.0	5.0	7.036E+01
55.0	5.0	4.654E+01
50.0	5.0	3.445E+01
45.0	5.0	2.808E+01
40.0	5.0	2.499E+01
35.0	5.0	2.422E+01
30.0	5.0	2.551E+01
25.0	5.0	2.860E+01
20.0	5.0	2.998E+01
15.0	5.0	1.874E+01
10.0	5.0	3.460E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	1.215E+02
60.0	10.0	6.946E+01
55.0	10.0	4.558E+01
50.0	10.0	3.332E+01
45.0	10.0	2.660E+01
40.0	10.0	2.283E+01
35.0	10.0	2.072E+01
30.0	10.0	1.928E+01
25.0	10.0	1.724E+01
20.0	10.0	1.320E+01
15.0	10.0	7.144E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	1.200E+02
60.0	15.0	6.800E+01
55.0	15.0	4.406E+01
50.0	15.0	3.159E+01
45.0	15.0	2.445E+01
40.0	15.0	1.999E+01
35.0	15.0	1.678E+01
30.0	15.0	1.308E+01
25.0	15.0	1.066E+01
20.0	15.0	6.956E-00
15.0	15.0	2.666E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	1.178E+02
60.0	20.0	6.606E+01
55.0	20.0	4.210E+01
50.0	20.0	2.944E+01
45.0	20.0	2.197E+01
40.0	20.0	1.702E+01
35.0	20.0	1.324E+01
30.0	20.0	9.938E-00
25.0	20.0	6.786E-00
20.0	20.0	3.648E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	1.152E+02
60.0	25.0	6.371E+01
55.0	25.0	3.980E+01
50.0	25.0	2.706E+01
45.0	25.0	1.940E+01
40.0	25.0	1.423E+01
35.0	25.0	1.031E+01
30.0	25.0	7.079E-00
25.0	25.0	4.217E-00
20.0	25.0	9.843E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	1.121E+02
60.0	30.0	6.102E+01
55.0	30.0	3.728E+01
50.0	30.0	2.457E+01
45.0	30.0	1.690E+01
40.0	30.0	1.174E+01
35.0	30.0	7.932E-00
30.0	30.0	4.903E-00
25.0	30.0	2.173E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	1.087E+02
60.0	35.0	5.808E+01
55.0	35.0	3.462E+01
50.0	35.0	2.207E+01
45.0	35.0	1.453E+01
40.0	35.0	9.536E-00
35.0	35.0	5.930E-00
30.0	35.0	3.059E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	1.048E+02
60.0	40.0	5.493E+01
55.0	40.0	3.187E+01
50.0	40.0	1.961E+01
45.0	40.0	1.231E+01
40.0	40.0	7.549E-00
35.0	40.0	4.123E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	1.006E+02
60.0	45.0	5.159E+01
55.0	45.0	2.906E+01
50.0	45.0	1.718E+01
45.0	45.0	1.019E+01
40.0	45.0	5.650E-00
35.0	45.0	2.139E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	9.608E+01
60.0	50.0	4.804E+01
55.0	50.0	2.616E+01
50.0	50.0	1.474E+01
45.0	50.0	8.056E-00
40.0	50.0	3.563E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	9.100E+01
60.0	55.0	4.420E+01
55.0	55.0	2.309E+01
50.0	55.0	1.213E+01
45.0	55.0	5.636E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	8.519E+01
60.0	60.0	3.989E+01
55.0	60.0	1.963E+01
50.0	60.0	9.072E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	8.189E+01
60.0	62.5	3.745E+01
55.0	62.5	1.763E+01
50.0	62.5	7.103E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	7.819E+01
60.0	65.0	3.472E+01
55.0	65.0	1.533E+01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	67.5	7.397E+01
60.0	67.5	3.159E+01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 15.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	6.903E+01
60.0	70.0	2.785E+01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	6.310E+01
60.0	72.5	2.317E+01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	1.142E+02
60.0	0.0	6.758E+01
55.0	0.0	4.822E+01
50.0	0.0	4.225E+01
45.0	0.0	5.215E+01
40.0	0.0	1.166E+05
35.0	0.0	2.057E+01
30.0	0.0	8.142E-00
25.0	0.0	2.650E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	1.138E+02
60.0	5.0	6.715E+01
55.0	5.0	4.749E+01
50.0	5.0	4.035E+01
45.0	5.0	4.207E+01
40.0	5.0	3.896E+01
35.0	5.0	1.752E+01
30.0	5.0	7.594E-00
25.0	5.0	2.423E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	1.127E+02
60.0	10.0	6.590E+01
55.0	10.0	4.554E+01
50.0	10.0	3.622E+01
45.0	10.0	3.101E+01
40.0	10.0	2.323E+01
35.0	10.0	1.325E+01
30.0	10.0	6.353E-00
25.0	10.0	1.777E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	1.110E+02
60.0	15.0	6.399E+01
55.0	15.0	4.290E+01
50.0	15.0	3.191E+01
45.0	15.0	2.436E+01
40.0	15.0	1.699E+01
35.0	15.0	1.012E+01
30.0	15.0	4.973E-00
25.0	15.0	4.118E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	1.086E+02
60.0	20.0	6.159E+01
55.0	20.0	3.997E+01
50.0	20.0	2.810E+01
45.0	20.0	1.996E+01
40.0	20.0	1.328E+01
35.0	20.0	7.824E-00
30.0	20.0	3.659E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	1.058E+02
60.0	25.0	5.885E+01
55.0	25.0	3.699E+01
50.0	25.0	2.481E+01
45.0	25.0	1.671E+01
40.0	25.0	1.065E+01
35.0	25.0	6.025E-00
30.0	25.0	2.378E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	1.024E+02
60.0	30.0	5.586E+01
55.0	30.0	3.405E+01
50.0	30.0	2.192E+01
45.0	30.0	1.410E+01
40.0	30.0	8.582E-00
35.0	30.0	4.507E-00
30.0	30.0	6.606E-01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	9.871E+01
60.0	35.0	5.271E+01
55.0	35.0	3.118E+01
50.0	35.0	1.932E+01
45.0	35.0	1.189E+01
40.0	35.0	6.835E-00
35.0	35.0	3.097E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	9.453E+01
60.0	40.0	4.940E+01
55.0	40.0	2.838E+01
50.0	40.0	1.693E+01
45.0	40.0	9.935E-00
40.0	40.0	5.256E-00
35.0	40.0	1.466E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	8.993E+01
60.0	45.0	4.596E+01
55.0	45.0	2.561E+01
50.0	45.0	1.468E+01
45.0	45.0	8.115E-00
40.0	45.0	3.696E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	8.488E+01
60.0	50.0	4.237E+01
55.0	50.0	2.285E+01
50.0	50.0	1.250E+01
45.0	50.0	6.335E-00
40.0	50.0	1.795E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	7.933E+01
60.0	55.0	3.859E+01
55.0	55.0	2.005E+01
50.0	55.0	1.032E+01
45.0	55.0	4.446E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	7.321E+01
60.0	60.0	3.458E+01
55.0	60.0	1.717E+01
50.0	60.0	8.055E-00
45.0	60.0	1.910E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	6.992E+01
60.0	62.5	3.248E+01
55.0	62.5	1.567E+01
50.0	62.5	6.835E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	6.646E+01
60.0	65.0	3.031E+01
55.0	65.0	1.413E+01
50.0	65.0	5.502E-00

LATITUDE	LONGITUDE	DENSITY/KT
60.0	67.5	2.806E+01
55.0	67.5	1.252E+01
50.0	67.5	3.943E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	5.904E+01
60.0	70.0	2.573E+01
55.0	70.0	1.084E+01
50.0	70.0	1.597E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 40.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	5.508E+01
60.0	72.5	2.331E+01
55.0	72.5	9.045E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	75.0	5.096E+01
60.0	75.0	2.081E+01
55.0	75.0	7.064E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	77.5	4.670E+01
60.0	77.5	1.822E+01
55.0	77.5	4.697E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	80.0	4.234E+01
60.0	80.0	1.554E+01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	82.5	3.788E+01
60.0	82.5	1.272E+01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	1.118E+02
60.0	0.0	6.775E+01
55.0	0.0	5.16[illegible]E+01
50.0	0.0	5.608E+01
45.0	0.0	6.483E+05
40.0	0.0	2.410E+01
35.0	0.0	1.037E+01
30.0	0.0	4.326E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	1.114E+02
60.0	5.0	6.716E+01
55.0	5.0	5.020E+01
50.0	5.0	4.813E+01
45.0	5.0	4.571E+01
40.0	5.0	2.118E+01
35.0	5.0	9.845E-00
30.0	5.0	4.128E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	1.102E+02
60.0	10.0	6.553E+01
55.0	10.0	4.682E+01
50.0	10.0	3.817E+01
45.0	10.0	2.883E+01
40.0	10.0	1.683E+01
35.0	10.0	8.600E-00
30.0	10.0	3.593E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	1.083E+02
60.0	15.0	6.317E+01
55.0	15.0	4.298E+01
50.0	15.0	3.162E+01
45.0	15.0	2.211E+01
40.0	15.0	1.349E+01
35.0	15.0	7.173E-00
30.0	15.0	2.833E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	1.058E+02
60.0	20.0	6.039E+01
55.0	20.0	3.932E+01
50.0	20.0	2.709E+01
45.0	20.0	1.807E+01
40.0	20.0	1.098E+01
35.0	20.0	5.807E-00
30.0	20.0	1.887E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	1.028E+02
60.0	25.0	5.737E+01
55.0	25.0	3.596E+01
50.0	25.0	2.361E+01
45.0	25.0	1.515E+01
40.0	25.0	8.998E-00
35.0	25.0	4.541E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	9.938E+01
60.0	30.0	5.423E+01
55.0	30.0	3.287E+01
50.0	30.0	2.074E+01
45.0	30.0	1.282E+01
40.0	30.0	7.324E-00
35.0	30.0	3.329E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	9.555E+01
60.0	35.0	5.100E+01
55.0	35.0	2.997E+01
50.0	35.0	1.823E+01
45.0	35.0	1.083E+01
40.0	35.0	5.840E-00
35.0	35.0	2.031E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	9.134E+01
60.0	40.0	4.769E+01
55.0	40.0	2.721E+01
50.0	40.0	1.596E+01
45.0	40.0	9.060E-00
40.0	40.0	4.440E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	8.676E+01
60.0	45.0	4.430E+01
55.0	45.0	2.453E+01
50.0	45.0	1.384E+01
45.0	45.0	7.396E-00
40.0	45.0	2.984E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	8.180E+01
60.0	50.0	4.081E+01
55.0	50.0	2.189E+01
50.0	50.0	1.180E+01
45.0	50.0	5.759E-00
40.0	50.0	8.446E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	7.642E+01
60.0	55.0	3.719E+01
55.0	55.0	1.925E+01
50.0	55.0	9.788E-00
45.0	55.0	4.015E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	7.059E+01
60.0	60.0	3.342E+01
55.0	60.0	1.657E+01
50.0	60.0	7.715E-00
45.0	60.0	1.644E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	6.751E+01
60.0	62.5	3.147E+01
55.0	62.5	1.520E+01
50.0	62.5	6.623E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	6.430E+01
60.0	65.0	2.947E+01
55.0	65.0	1.381E+01
50.0	65.0	5.456E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	67.5	6.098E+01
60.0	67.5	2.743E+01
55.0	67.5	1.238E+01
50.0	67.5	4.146E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	5.754E+01
60.0	70.0	2.535E+01
55.0	70.0	1.091E+01
50.0	70.0	2.472E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	5.401E+01
60.0	72.5	2.322E+01
55.0	72.5	9.387E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	75.0	5.038E+01
60.0	75.0	2.105E+01
55.0	75.0	7.768E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 45.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	77.5	4.667E+01
60.0	77.5	1.884E+01
55.0	77.5	5.993E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	80.0	4.291E+01
60.0	80.0	1.658E+01
55.0	80.0	3.860E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	82.5	3.912E+01
60.0	82.5	1.429E+01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	85.0	3.532E+01
60.0	85.0	1.193E+01

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	0.0	3.543E+05
60.0	0.0	6.028E+01
55.0	0.0	3.025E+01
50.0	0.0	1.599E+01
45.0	0.0	8.048E-00
40.0	0.0	3.103E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	5.0	1.309E+02
60.0	5.0	5.855E+01
55.0	5.0	2.989E+01
50.0	5.0	1.583E+01
45.0	5.0	7.966E-00
40.0	5.0	3.043E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	10.0	1.071E+02
60.0	10.0	5.496E+01
55.0	10.0	2.892E+01
50.0	10.0	1.540E+01
45.0	10.0	7.726E-00
40.0	10.0	2.865E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	15.0	9.739E+01
60.0	15.0	5.131E+01
55.0	15.0	2.757E+01
50.0	15.0	1.474E+01
45.0	15.0	7.347E-00
40.0	15.0	2.567E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	20.0	9.121E+01
60.0	20.0	4.806E+01
55.0	20.0	2.604E+01
50.0	20.0	1.392E+01
45.0	20.0	6.854E-00
40.0	20.0	2.138E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	25.0	8.647E+01
60.0	25.0	4.517E+01
55.0	25.0	2.444E+01
50.0	25.0	1.300E+01
45.0	25.0	6.269E-00
40.0	25.0	1.528E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	30.0	8.238E+01
60.0	30.0	4.251E+01
55.0	30.0	2.283E+01
50.0	30.0	1.201E+01
45.0	30.0	5.611E-00
40.0	30.0	2.035E-01

LATITUDE	LONGITUDE	DENSITY/KT
65.0	35.0	7.858E+01
60.0	35.0	3.999E+01
55.0	35.0	2.123E+01
50.0	35.0	1.098E+01
45.0	35.0	4.888E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	40.0	7.489E+01
60.0	40.0	3.755E+01
55.0	40.0	1.964E+01
50.0	40.0	9.934E-00
45.0	40.0	4.098E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	45.0	7.121E+01
60.0	45.0	3.516E+01
55.0	45.0	1.806E+01
50.0	45.0	8.861E-00
45.0	45.0	3.216E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	50.0	6.749E+01
60.0	50.0	3.279E+01
55.0	50.0	1.649E+01
50.0	50.0	7.769E-00
45.0	50.0	2.150E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	55.0	6.372E+01
60.0	55.0	3.042E+01
55.0	55.0	1.492E+01
50.0	55.0	6.652E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	60.0	5.988E+01
60.0	60.0	2.806E+01
55.0	60.0	1.336E+01
50.0	60.0	5.492E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	62.5	5.794E+01
60.0	62.5	2.688E+01
55.0	62.5	1.258E+01
50.0	62.5	4.886E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	65.0	5.598E+01
60.0	65.0	2.570E+01
55.0	65.0	1.180E+01
50.0	65.0	4.252E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	67.5	5.401E+01
60.0	67.5	2.453E+01
55.0	67.5	1.103E+01
50.0	67.5	3.573E-00

NEUTRON DEPOSITION DENSITY FOR BURST LATITUDE = 65.0
FOR CASE YR = 1.0

LATITUDE	LONGITUDE	DENSITY/KT
65.0	70.0	5.204E+01
60.0	70.0	2.336E+01
55.0	70.0	1.025E+01
50.0	70.0	2.817E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	72.5	5.006E+01
60.0	72.5	2.219E+01
55.0	72.5	9.472E-00
50.0	72.5	1.837E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	75.0	4.808E+01
60.0	75.0	2.103E+01
55.0	75.0	8.688E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	77.5	4.610E+01
60.0	77.5	1.988E+01
55.0	77.5	7.900E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	80.0	4.413E+01
60.0	80.0	1.873E+01
55.0	80.0	7.102E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	82.5	4.218E+01
60.0	82.5	1.760E+01
55.0	82.5	6.291E-00

LATITUDE	LONGITUDE	DENSITY/KT
65.0	85.0	4.024E+01
60.0	85.0	1.648E+01

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